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Date: August 11, 1997
Docket No.: 3176-0101P

Assistant Commissioner for Patents
Box PATENT APPLICATION
Washington, D.C. 20231

Sir:

Transmitted herewith for filing is the patent application of

Inventor(s): YANG, Ta-yung

For: ADAPTIVE SLOPE COMPENSATOR FOR CURRENT MODE POWER CONVERTER

Enclosed are:

X A specification consisting of 8 pages

X 8 sheet(s) of Formal drawings

___ An assignment of the invention

___ Certified copy of Priority Document(s)

X Executed Declaration ___ Original X Photocopy

X A verified statement to establish small entity status under 37 CFR 1.9 and 37 CFR 1.27

___ Preliminary Amendment

___ Information Disclosure Statement, PTO-1449 and reference(s)

___ Other ______________________

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3176-0101P

The filing fee has been calculated as shown below:

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BASIC FEE	*********** *********** ***********	********** ********** **********	***** ***** *****	$770.00	or	**** **** ****	$385.00
TOTAL CLAIMS	5 - 20 =	0	x22 =$	0.00	or	x 11 = $	0.00
INDEPENDENT	1 - 3 =	0	x80 =$	0.00	or	x 40 = $	0.00
MULTIPLE DEPENDENT CLAIM PRESENTED no			+260 = $	0.00	or	+130 = $	0.00
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Respectfully submitted,

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3176-101P

In the United States Patent and Trademark Office

First/Sole Applicant: Yang Ta-yung

Joint/Second Applicant:

Title: " Adaptive Slope Compensator for Current Mode Power Converter "

Small Entity Declaration - Small Business Concern

I hereby declare that I am

- ☐ the owner of the small business concern identified below:
- ☒ an officer of the small business concern empowered to act on behalf of the concern identified below:

Name of Concern: System General Corporation

Address of Concern: 1603A South Main Street Milpitas, CA 95035

U.S.A.

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.3-18, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the above entitled invention of the above applicants and the specification filed herewith.

I acknowledge a duty to file, in the above application for patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate (37 CFR 1.28(b)).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Don Yang

Signature of Officer of Small Business Concern

Aug/4/97

Date

Don Yang / Vice President

Name and Title of Officer

1603A South Main Street Milpitas, CA 95035 U.S.A.

Address of Officer

3176-101P

In the United States Patent and Trademark Office

First/Sole Applicant: Yang Ta-yung

Joint/Second Applicant: ____________________

Title:" Adaptive Slope Compensator for Current Mode Power Converter "

Small Entity Declaration -Independent Inventor (s)

As a below-named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9 (c) for purposes of paying reduced fees under Section 41 (a) and (b) of Title 35 United States Code, to the Patent and Trademark Office with regard to my above-identified invention described in the specification filed herewith. I have not assigned, granted, conveyed, or licensed – and am under no obligation under any contract or law to assign, grant, convey, or license-any rights in the invention to either (a) any person who could not be classified as an independent inventor under 37 CFR 1.9 (c) if that person had made the invention, or (b) any concern which would not qualify as either (i) a small business concern under 37 CFR 1.9 (d) or (ii) a nonprofit organization under 37 CFR 1.9 (e).

Each person, concern, or organization to which I have assigned, granted, conveyed, or licensed - or am under an obligation under contract or law to assign, grant, convey, or license – any rights in the invention is listed below:

☐ There is no such person, concern, or organization.

☒ Any applicable person, concern, or organization is listed below:*

Full Name: System General Corporation

Address: 1603A South Main Street Milpitas, CA 95035
U.S.A.

I acknowledge a duty to file, in the above application for patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate (37 CFR 1.28(b)).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Tom Yang	
Signature of Sole/First Inventor	Signature of Joint/Second Inventor
Yang Ta-yung	
Print Name of Sole/First Inventor	Print Name of Joint/Second Inventor
July 1, 1997	
Date of Signature	Date of Signature

*Note: A separate Small Entity Statement is required from any listed entity.

Patent Application of

Yang Ta-yung

for

Adaptive Slope Compensator for Current Mode Power Converter

Field of Invention

This invention relates to the power converters and more specifically to current mode power converters.

Background of the Invention

Various power converter are available for transforming an unregulated input voltage to a regulated output voltage with a specific magnitude. The technologies of power conversion such as forward and flyback are well described as the prior art. Although the advantages of current mode control over voltage mode control has been amply demonstrated, the slope compensation has to be added in the current loop to solve the instability problems. Many texts can explain the operation of current mode and the slope compensation, such as (a) Keith H. Billings " Switchmode Power Supply Handbook" McGraw-Hill Book Co., p3.148-p3.150 (b) Abraham I. Pressman " Switching Power Supply Design" McGraw-Hill Book Co., p105-p136 ; p143-p165. (c) Modelling, Analysis and Compensation of the Current-Mode Converter" Unitrode Corp. Application Note U-97 (d) "Practical Considerations in Current Mode Power Supplies" Unitrode Corp. Application Note U-111. However, there still exist several drawbacks in conventional slope compensation technologies. Thus, in order to solve the problem and improve the performance, mathematical analysis and practical circuit test have been performed to establish the fundamental of this invention. The characteristic analysis of conventional slope compensation are listed as follows,

(**A**) Advantage I : Slope compensation stabilize the current loop

A general circuit of current mode power converter is shown in **Fig. 1**, its symbols defined are :

Pwr: power converter	T_M: power transformer
N_P: primary turn ratio of T_M	N_S: secondary turn ratio of T_M
L_P: primary inductance of T_M	L_S: secondary inductance of T_M
I_P: primary current of T_M	I_{PP}: primary peak current of T_M
I_{PA}: primary average current of T_M	I_S: secondary current of T_M
I_{SP}: secondary peak current of T_M	I_{SA}: secondary average current of T_M
T: switching period of Pwr	T_{ON}: turn-on time of T
T_{OFF}: turn-off time of T	V_O: output voltage of Pwr
V_{IN}: input voltage of Pwr	V_{SL}: voltage of slope compensation signal
Verr: output voltage of the error amplifier	
V_{RP}: sensed voltage of resistor R_P	

There are two distinctly different operating mode of power converters, discontinuous and continuous. If a higher power conversion efficiency is concerned, the continuous is much more widely used than the discontinuous mode. The purpose of following analysis is to figure out the criterion of stabilizing the current loop in which a minimum magnitude of the slope compensation has to be added, if the power converter is operating in *continuous current mode* or if the duty cycle of power converter is greater than 50 percent. Slope m is the down slope ; $m = dIs / dt = Vo / Ls$. **Fig. 2** shows the continuous mode current waveform, Ip and Is. $I_{SA} = I_{SP} - (dIs/2) = I_{SP} - (m/2) \bullet dt$; $I_{SA} = I_{SP} - (m/2) \bullet T_{OFF}$; $I_{SP} = I_{SA} + (m/2) \bullet (T - T_{ON})$; The peak voltage V_{RP} across the primary current-sensing resistor R_P is $V_{RP} = I_{PP} \bullet R_P = I_{SP} \bullet (Ns / Np) \bullet R_P = [\, I_{SA} + (m/2) \bullet (T - T_{ON})\,] \bullet Ns / Np) \bullet R_P$. Adding the slope compensation to V_{RP}, this feedback signal is stated as $V_C = V_{RP} + (V_{SL}/T) \bullet \Delta T = V_{RP} + (V_{SL}/T) \bullet (\Delta T_{ON} + \Delta T_{OFF})$;

$$V_C = \frac{Ns}{Np} R_P I_{SA} + \frac{Ns}{Np} R_P \frac{mT}{2} + \Delta T_{ON} \left(\frac{V_{SL}}{T} - \frac{Ns}{Np} R_P \frac{m}{2} \right) + \Delta T_{OFF} \frac{V_{SL}}{T} \qquad (1)$$

Since an amount of energy delivered in a time T represents power , at the end of one period, power drawn from V_{IN} is $P = L_P I_P{}^2/(2T) = [L_P \bullet (I_{PP}{}^2 - I_{PA}{}^2)]/(2T)$, But $I_{PP} = I_{PA} + \Delta I_P = I_{PA} + (V_{IN}/L_P) \bullet \Delta T$, Then

$$P = \frac{1}{2TL_P} (V_{IN}{}^2 . T_{ON}{}^2) + V_{IN} . I_{PA} \frac{T_{ON}}{T} \qquad (2)$$

The current I_{PA} is an energy can not completely delivery to the load during the off (T_{OFF}) time and still remaining in the transformer. Thus the magnitude of the current I_{PA} is related to the T_{OFF} and T_{ON}. It is easily verified from equation (2), that the feedback loop regulate the output of power converter by controlling T_{ON} . The output voltage Vo is sensed and compared to a reference voltage in the error amplifier (EA). The amplified error voltage Verr (voltage loop signal) is fed to a voltage comparator and compare with the Vc (current loop signal). As shown in **Fig. 1**, the on time starts at the clock pulse of oscillator (osc) and ends when the Vc ramp equals to level of the Verr, thereby the adjustment of T_{ON} is in proportion to the magnitude of voltage Vc and Verr. Mathematically the relationship between Vc and T_{ON} is $\partial V_C / \partial T_{ON} \geq 0$. The deviation from equation (1) can be stated as

$$\frac{\partial Vc}{\partial T_{ON}} = \frac{V_{SL}}{T} - \frac{Ns}{Np} R_P \frac{m}{2}$$

This can be seen quantitatively as

$$\frac{V_{SL}}{T} \geq \frac{Ns}{Np} R_P \frac{m}{2} \qquad (3)$$

If the change of T_{ON} is out of proportional to the Vc , $\partial V_C / \partial T_{ON} < 0$, then the feedback loop will non-linearly oscillate. Thus the criterion of equation (3) must be satisfied to insure the loop stable.

(B) Advantage II : Slope compensation improve the linearity of current loop

Before adding the slope compensation, the signal Vc is equal to V_{RP} :

$$\Delta I_P = \frac{V_{IN}}{Lp} . \Delta T \quad \text{———} \quad (4)$$

$$V_{RP} = (I_{PA} + \frac{V_{IN}}{Lp} \Delta T_{ON}) . R_P \quad \text{———} \quad (5)$$

This is seen from equation (2), (4), (5), when the output power remain constant, the T_{ON} increase and ΔI_P decrease as V_{IN} goes down. The current waveform corresponding to the V_{IN} and T_{ON} is shown in **Fig. 3** . The current feedback loop signal compare with the voltage feedback loop signal will control the output power and regulate the output voltage, it is obvious the control loop will lose the linearity and noise immunity as V_{IN} goes down. This disadvantage can be improved by adding the slope compensation.

$$V_C = V_{RP} + \frac{V_{SL}}{T} (\Delta T_{ON} + \Delta T_{OFF})$$

$$= I_{PA}.R_P + \frac{V_{SL}}{T} \Delta T_{OFF} + \Delta T_{ON} (\frac{V_{IN}}{Lp}.R_P + \frac{V_{SL}}{T}) \quad \text{———} \quad (6)$$

The slope compensation element remains a minimum linearity of the control loop.

(C) Disadvantage I : A dummy load or the minimum load is required to avoid the unstable oscillation while no load or light load conditions

The current mode power converter per se are known, it will operate in discontinuous mode while the output is in no load or light load conditions and it may operate in continuous mode while the output power is high or the input voltage is low. A minimum magnitude of slope compensation must be added as equation (3), as long as the power converter it may operate in the continuous mode. While the power converter is operating in discontinuous mode, its slope compensation included current feedback loop signal Vc is

$$V_C = \frac{V_{IN}}{Lp} . R_P . \Delta T_{ON} + \frac{V_{SL}}{T} (\Delta T_{ON} + \Delta T_{OFF}) \quad \text{———} \quad (7)$$

this signal waveform is shown in **Fig. 4**. It illustrates the mechanism of a nonlinear deviation in the power control. If the signal Verr goes down due to the regulation, its voltage move from *point C* to *point A* or *point B* will cause a nonlinear deviation. Since the voltage level of *point A* is equal to *point B*, but the on time (T_{ON}) of *point A* and *point B* is different. The difference is (T_{ONB}-T_{ONA}) which cause a deviation P_d in the power control.

$$P_d = \frac{V_{IN}^2}{2TLp} (T_{ONB}^{2} - T_{ONA}^{2}) \quad \text{———} \quad (8)$$

Because of this, the effect is then an oscillation which commences at every change in signal Verr and which may continue for some time. Two conventional approach to solve this problem are (a) To equip with a dummy load in the output. This yield [$I_P \cdot R_P > (V_{SL}/T)$] during the no load or light conditions. However this will consume a power of dummy load. (b) To require consuming a minimum power in the load, however this can not meet the requirement of the power management. The embodiment of power management is to manage the system only consuming the power during the operation. And no power or few power is consumed during the non-operation (sleep mode). With

respect to the power converter in a power management application, how to save the power in the no load or light load conditions is a major requirement.

(D) Disadvantage II : Less than ideal line voltage regulation

Consider how the power converter regulates against line voltage changes. As V_{IN} goes up, the Vo will eventually go up. Then after delay in getting through the voltage feedback loop , Verr will goes down and the output voltage will be brought back down. Beside the mechanism of this, there is a shortcut correction in the current mode operation. As V_{IN} goes up, the slope of current Ip increase and hence the slope of the ramp of V_{RP} increases. Now the faster ramp equals Verr and the on time (T_{ON}) is shortened. Output voltage changes resulting from input voltage changes will be smaller in amplitude and shorter in duration because of this feedforward characteristic. The output voltage Vo is

$$V_O = V_{IN}\,\frac{Ns}{Np}\,\frac{T_{ON}}{T_{OFF}}$$

By using equation (7), if it Vc = Verr, then we obtain

$$T_{ON} = \frac{Verr}{\left(\frac{V_{IN}}{Lp} \bullet Rp + \frac{V_{SL}}{T}\right)} \qquad (9)$$

We can find that the loop gain of this feedforward characteristic will be reduced by increasing the magnitude of slope compensation V_{SL}/T. Thus, increase the magnitude of slope compensation will decrease the loop gain of current feedback loop and then reduce the capability of line voltage regulation.

Figures (5) and **(6)** show two conventional methods of implementing slope compensation. There are unable to solve the problems in the previous description and unable to operate in wide input ranges (V_{IN}).

Objects of the Invention

In view of the above advantages and disadvantages with the prior approach, the object of the present invention is to provide a novel solution to avoid these disadvantages and achieve a wide input ranges power conversion. Besides, the objects of the present invention are :

(a) to improve the power conversion efficiency and save the energy.
(b) to shrink the volume of power converter and save the material cost.

These objects are realized in a novel slope compensation construction which allow the power converter to operate in continuous mode under the medium load or heavy load condition. And, no minimum load, no dummy load is required under the light load or no load conditions. The adaptive function of present invention which will enhance the linearity of control loop in response to a lower input voltage and permits a higher duty cycle (T_{ON} / T_{OFF}), thereby a smaller input capacitor is only need. In an off-line power

converters, this high voltage, high capacity electrolytic capacitor are expensive and large. It is much more compact and cost effective to use a smaller input capacitor.

Summary of the Invention

In accordance with the present invention, a programmable current source comprises a capacitor, generating a slope signal; This slope signal is added to current feedback loop for slope compensation; the slope signal is synchronized with the switching signal of power converter via the connection of a diode; the input of programmable current source having a resistor, coupled to the voltage feedback loop of power converter, and generating a slope signal in response to the input voltage and output load of power converter wherein the slew rate and magnitude of the slope signal is responsive to the input voltage and output load, and the signal width of the slope signal is equal to the pulse width of switching signal of power converter.

The Drawing

Fig. (1) is a simplified circuit illustrating current mode power converter;
Fig. (2) shows the continuous mode current waveforms;
Fig. (3) shows the current waveform under relatively high and relatively low V_{IN};
Fig. (4) is the current loop feedback signal, in which the slope compensation signal is added, illustrates the mechanism of a nonlinear deviation in the power control;
Fig. (5) and (6) show, respectively, two forms of prior art circuits;
Fig. (7) is a schematic diagram illustrating a preferred embodiment of the invention;
Fig. (8) is the voltage waveform of ripple in input capacitor.

Detailed Description of Preferred Embodiment

Fig. (1) show an embodiment of current mode power converter constructed in accordance with the invention. PWM controller U_1 is a general control circuit for current mode power conversion. The switching signal Vsw (the output of U_1) drive a switching MOSFET Q_2. A transformer T_M is placed in series with V_{IN} and Q_2 for the power transfer. Switching frequency is determined by capacitor C_3 and the oscillator (osc) in U_1. Due to the *Latch* of U_1 is set by osc and reset by the comparator (Comp) in U_1, the on time starts at the clock pulse of osc and ends when the voltage level of signal from current feedback loop **200** equals to the voltage level of signal from voltage feedback loop **150**. The voltage feedback loop consists error amplifier U_3 and optocoupler U_2. The output voltage of power converter, Vo, is sensed and compared to a reference voltage in the error amplifier U_3. The optocoupler U_2 is required for the isolation in an off-line power converter, otherwise the amplified error voltage can be directly fed to the comparator of U_1. Another input to the comparator is the current feedback signal in which the primary current of transformer T_M is sensed by resistor R_p, and it is coupled to U_1 via the low pass filter R_5 and C_5. Adaptive slope compensator **100** have a pnp transistor Q_1, and incorporates resistors R_1, R_2, R_3 to form a programmable current source. Power is supplied from V_R of U_1, it is a constant voltage (reference voltage) output of U_1. The output of programmable current source, the collector of Q_1, has a capacitor C_T connect

to ground, which serves to produce slope waveform, and provides the time constant for the slew rate of slope signal. A diode D_T is connected between the output of programmable current source and the output of U_1(Vsw), which serves to synchronize the slope signal **250** with the switching signal Vsw, **300**. Bridge by the series of D_1 and R4, slope signal **250** is added to the current loop **200** . Via resistor R_1, the input of programmable current source is connected to any suitable means, exemplified here to V_{FB}, a voltage feedback loop signal, and thereby the output current of programmable current source is effected by input voltage V_{IN} and output power P_O of power converter.

Operation

The operation of Fig (7) in accordance with the invention is as follows :
During the on time (T_{ON}), the switching signal Vsw is high and diode D_T is off, capacitor C_T is charged by the programmable current source. Mathematically this can be stated as

$$V_{SL} = \frac{I_{R3} \cdot \Delta T}{C_T}$$

if the gain (h_{FE}) of Q1 is enough high, then

$$I_{R3} = (V_{R2} - V_{EB(Q1)}) / R_3$$

$$V_{R2} = (V_R - V_{FB}) \bullet [R_2 / (R_1 + R_2)]$$

The equation can be written as

$$V_{SL} = \frac{\Delta T}{R3.C_T}[(V_R - V_{FB}) \bullet \frac{R2}{R1+R2} - V_{EB(Q1)}] \tag{10}$$

$$\frac{\partial V_{SL}}{\partial V_{FB}} = \frac{-R2}{R3(R1+R2)C_T}.\Delta T \tag{11}$$

Since the change of V_{FB} is direct proportion to the change of V_{IN} and inverse proportion to the change of output power P_O, $\Delta V_{FB} = +K_1 \Delta V_{IN} - K_2 \Delta P_O$, where K_1, K_2 are loop gain constant of voltage feedback loop. Thus, the equation (11) can be stated as :

$$\Delta V_{SL} = \frac{R2}{R3(R1+R2)C_T}\Delta T \;.\; (-K_1 \Delta V_{IN} + K_2 \Delta P_O) \tag{12}$$

During the off time (T_{OFF}), the switching signal Vsw is low, diode D_T is on, capacitor C_T is discharged and the slope signal is reset to zero. Since the slope signal is synchronized with the switching signal, the rising time Δ T of slope signal is equal to the on time T_{ON}, thus equation (10) and (12) can be written as :

$$V_{SL} = \frac{T_{ON}}{R3C_T}[(V_R - V_{FB}). \frac{R2}{R1+R2} - V_{EB(Q1)})] \tag{13}$$

$$\Delta V_{SL} = (\frac{R2}{R1+R2})\frac{T_{ON}}{R3C_T}.(-K_1 \Delta V_{IN} + K_2 \Delta P_O) \tag{14}$$

In one specific implementation of the Fig. (7) arrangement, a 50W (P_O: $20V_{DC}/2.5A$) off-line power converter, the input voltage is rated $90V_{AC} \sim 265V_{AC}$ RMS, using a small input capacitor C_{IN} as 68 uF (microfarad), 400 volt electrolytic device. An EFD-30 ferrite core was used, operating in continuous mode under the medium load and full load. The efficiency of 85% ~ 88% was obtained responding to the change of V_{IN} ($90V_{AC} \sim 265V_{AC}$). And, less than 2W was consumed under the no load condition. According to the principle of equation (13), (14) and the measurement in the implementation, following results are observed :

(a) The operation of power converter is stable under the continuous mode and high duty cycle operation (e.g. T_{ON} / $T_{OFF} \approx 8/2$). The slope compensation is increased in response to the increase of output power or the decrease of input voltage V_{IN} respectively, and vice versa. The slope compensation is increased while V_{IN} is decreased, thereby providing an enough linearity for a low V_{IN}. The ripple voltage waveform of C_{IN} is shown in Fig. (8).

$$\varepsilon = P_O \, . \, t = \frac{1}{2} C_{IN} (V_b{}^2 - V_a{}^2)$$

$$C_{IN} = \frac{2 . Po . t}{V_b^2 - V_a^2} \; ; \text{where } V_b = 1.414 \, V_{IN\,(AC)}$$

Since a low Va is permit, means a small capacitor C_{IN} is allowed. The slope compensation is reduced in response to the increase of V_{IN}, thus maintain the performance of line regulation and audio susceptibilities.

(b) The slope signal will be reduced to zero under the light load and no load condition. Additionally, the slope signal is synchronized with the switching signal Vsw, in which the slope signal is reset to zero at the end of on time (T_{ON}). Therefore the oscillation under the light load or no load is avoided. The dummy load or minimum load is not required.

What is claimed is :

1. An adaptive slope compensator for compensating the current mode power converter comprising :

a programmable current source which generates programmable current;

a grounded capacitor associate with said programmable current generate the slope signal;

a switching diode to synchronized said slope signal with the switching signal of power converter,

wherein said slope signal is reset to zero in response to the off of said switching signal;

input stage of said programmable current source having an input resistor coupled to the voltage feedback loop of power converter to effect the magnitude of said programmable current and said slope signal;

wherein the slew rate of said slope signal is responsive to the signal of said voltage feedback loop during the on time of said switching signal; and

said slew rate and magnitude of said slope signal are direct proportion to the change of input voltage of power converter and are inverse proportion to the change of output power of power converter;

output stage of said programmable current source having an output diode and output resistor in series coupled to the current feedback loop of power converter to achieve the slope compensation.

2. Adaptive slope compensator in accordance with claim 1 wherein

said programmable current source includes a said grounded capacitor at its output terminal to generate the waveform of said slope signal and provide a time constant for the adjustment of said slew rate.

3. Adaptive slope compensator in accordance with claim 1 wherein

the output stage of said programmable current source has a said switching diode connect to said switching signal therein for synchronizing said slope signal.

4. Adaptive slope compensator in accordance with claim **1** wherein

said programmable current source comprising

a pnp transistor for the current control;

an emitter resistor connected between the emitter of said transistor and a constant voltage source for the current setting;

a base resistor connected between the base of said transistor and said constant voltage source for providing the bias to said transistor;

a said input resistor operatively connected to the base of said transistor and said voltage feedback loop for programming the magnitude of said programmable current;

wherein said programmable current is linearly responsive to said signal of said voltage feedback loop;

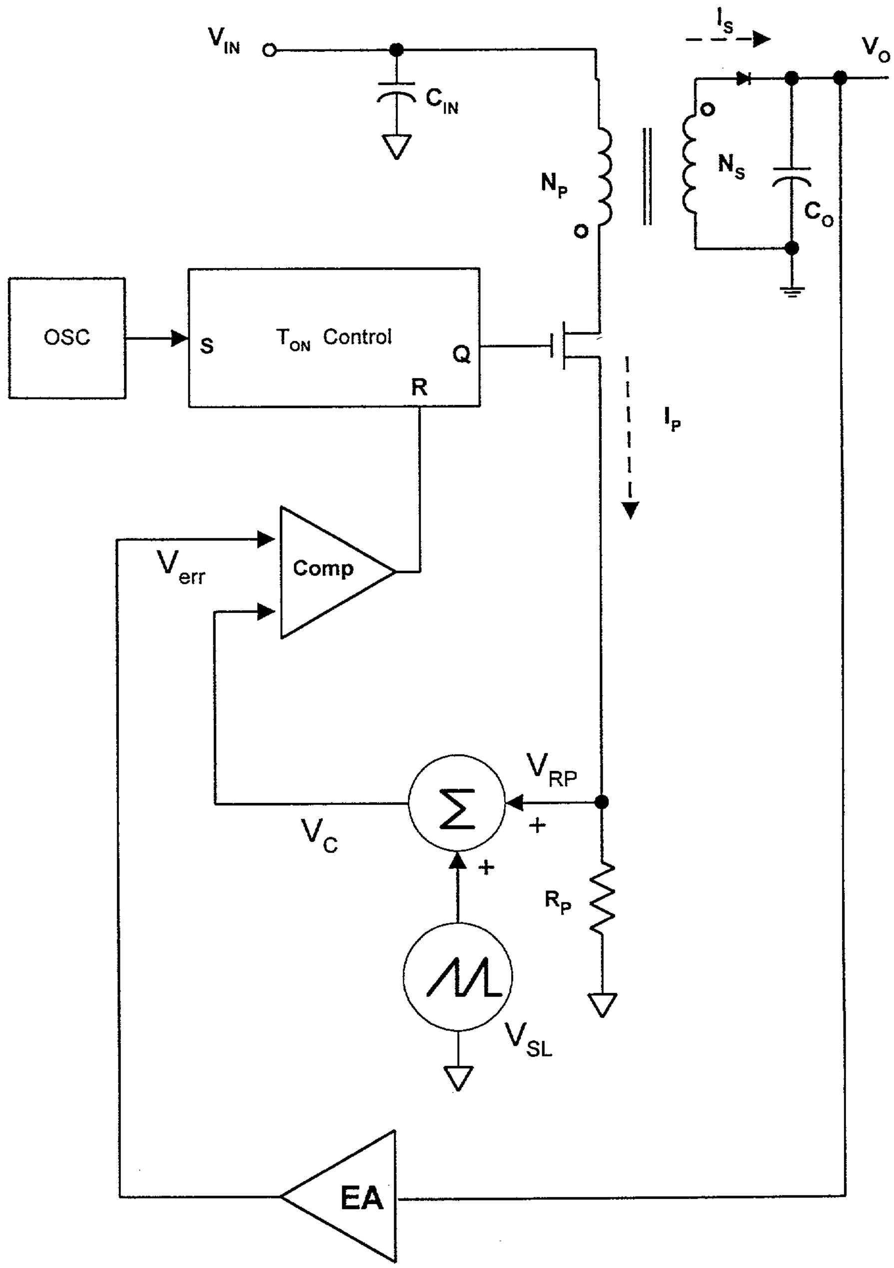
a filter capacitor positioned in the base of said transistor to eliminate the switching noise of power converter.

5. Adaptive slope compensator in accordance with claim **1** wherein

the magnitude of said signal of said voltage feedback loop is direct proportion to the change of input voltage and is inverse proportion to the change of output power.

Abstract

An adaptive slope compensator is disclosed which is used for compensating the current loop and improving the circuit performance of current mode power converter. The slope compensator is modulated by a voltage feedback loop signal of power converter, the slope compensation signal can thus automatically adjusted to optimize its operating parameters. Furthermore, by synchronizing with the switching signal of power converter, the slope compensation signal is reset to zero in response to the off of switching signal, thereby eliminating the oscillation problem of no load operation encountered by prior slope compensation designs.



V_{IN}
C_{IN}
I_S
V_O
N_P
N_S
C_O
OSC
S
T_{ON} Control
Q
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I_P
V_{err}
Comp
V_{RP}
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Fig . 1

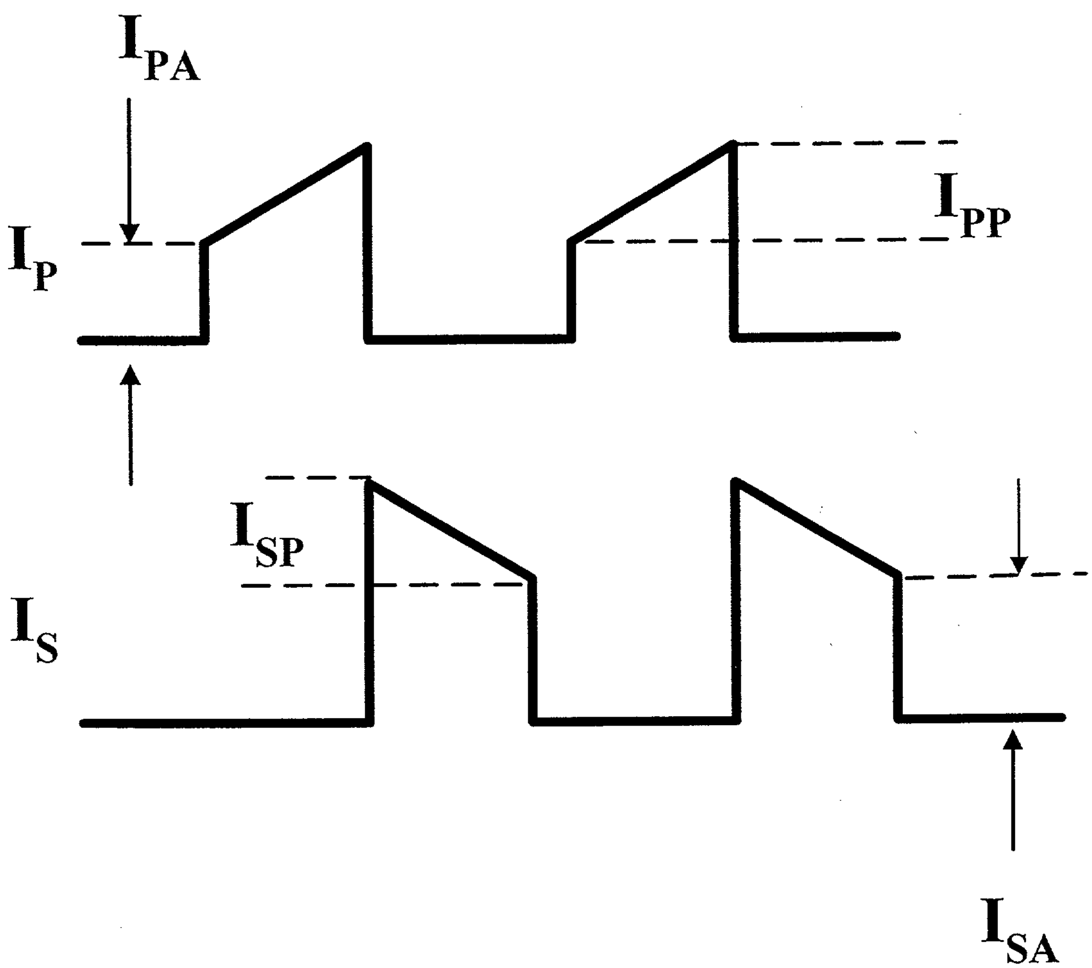


Fig . 2

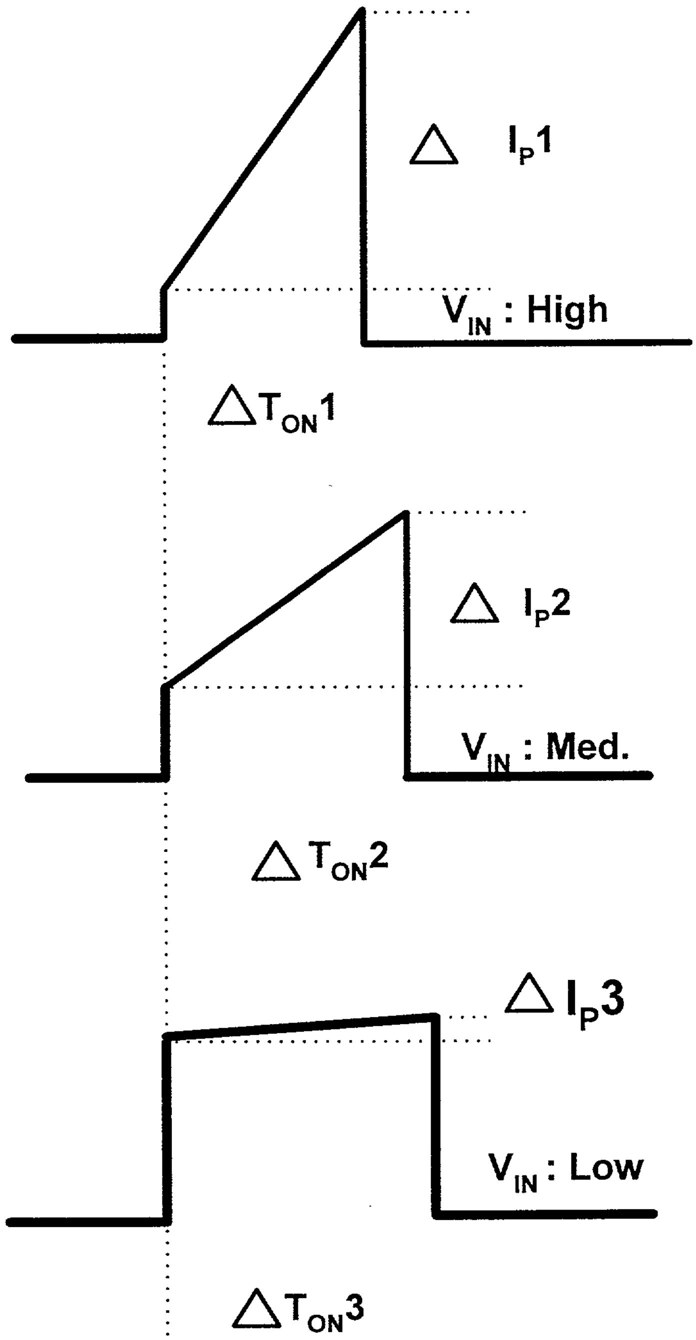


Fig . 3

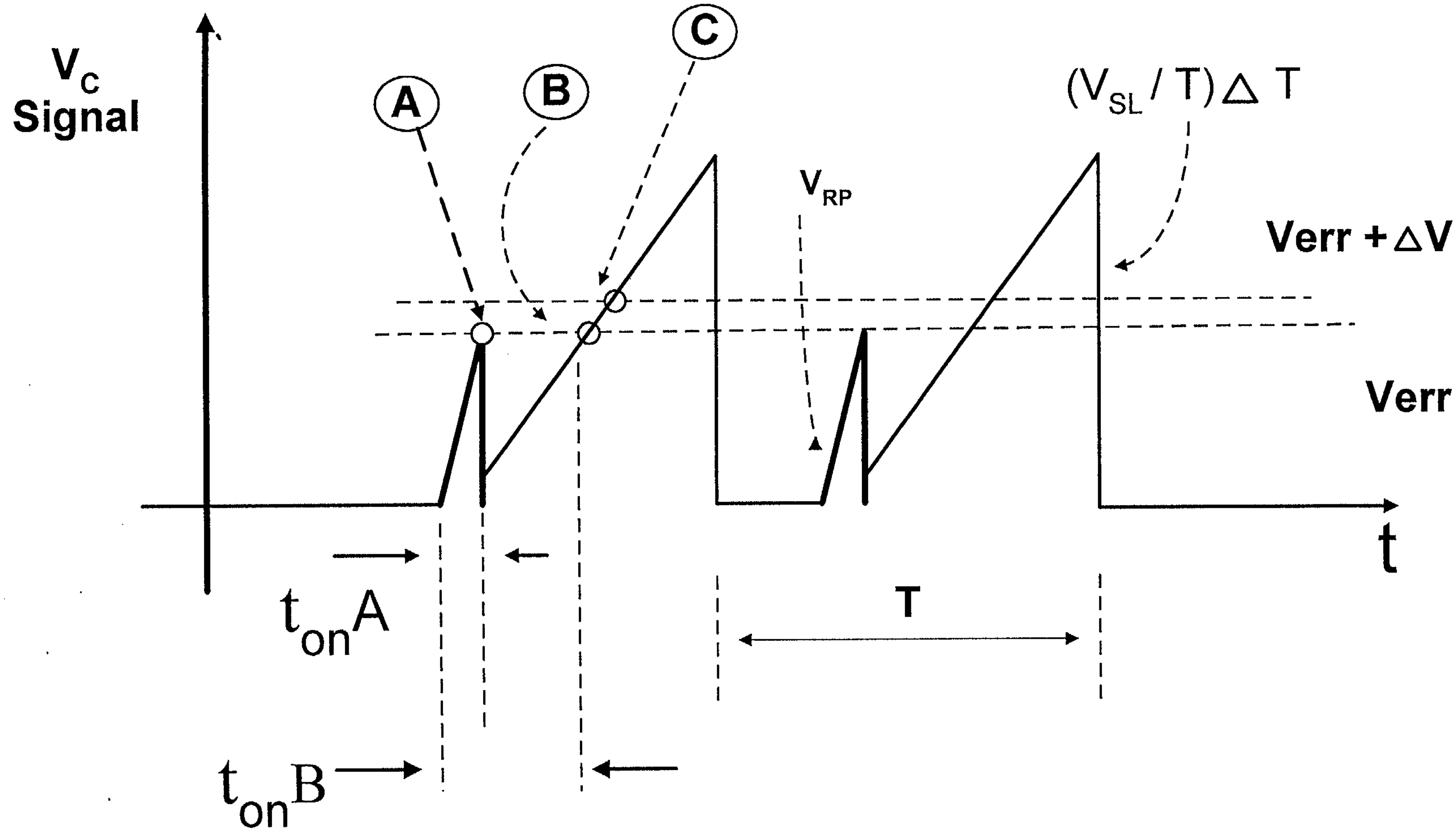


Fig . 4

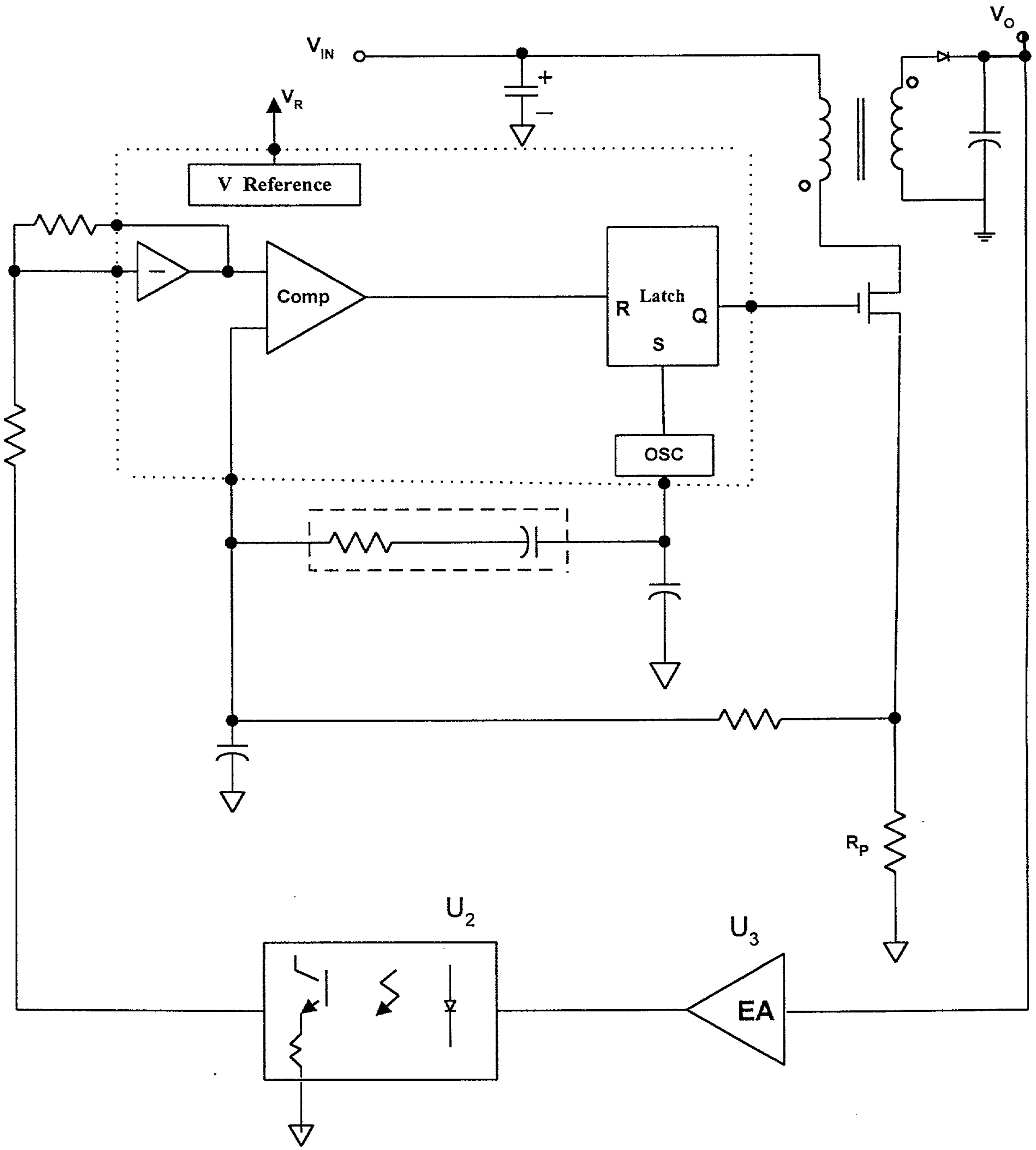


Fig . 5

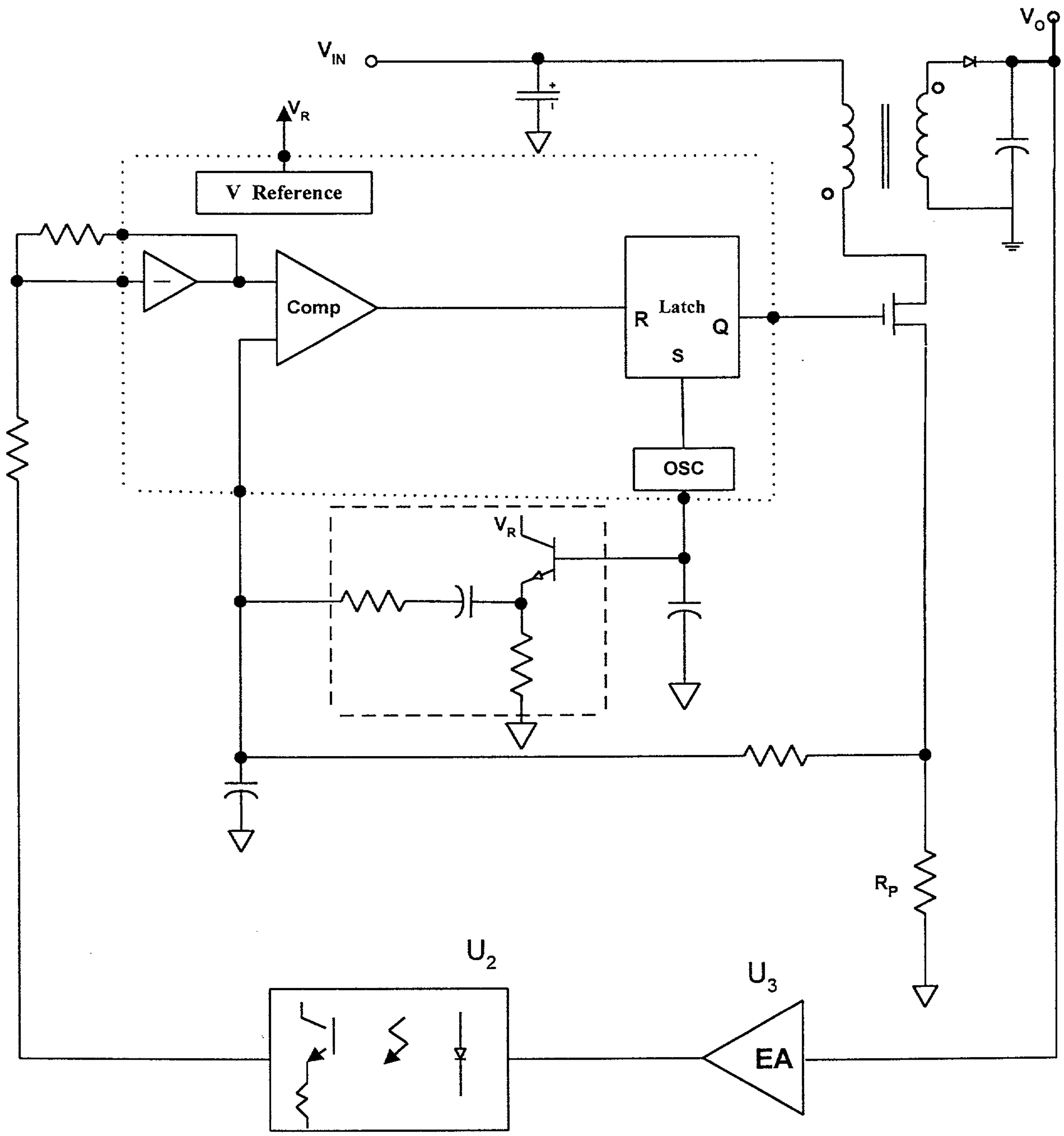
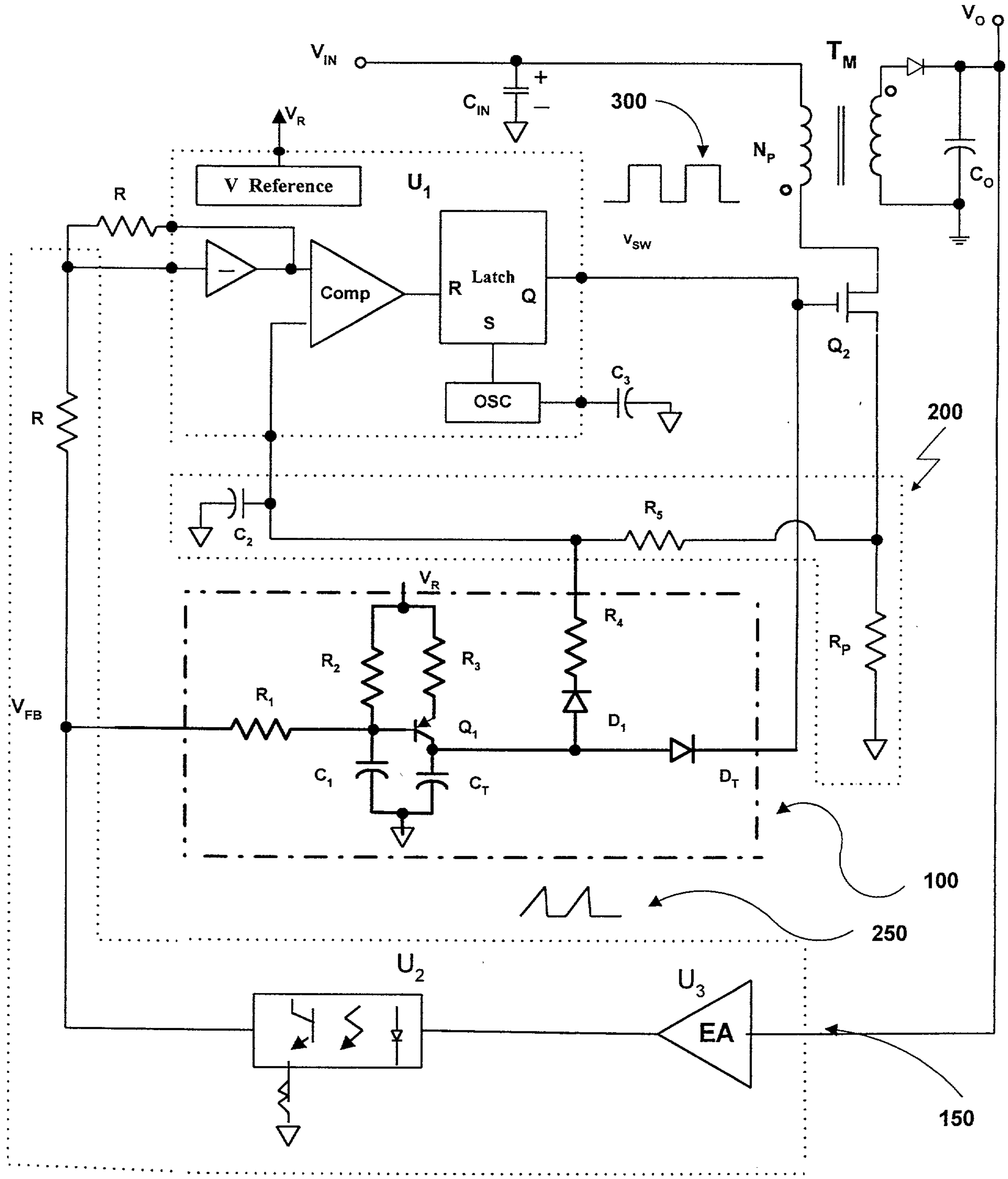


Fig . 6



V_O
V_IN
T_M
C_IN
+
300
V_R
V Reference
U_1
N_P
C_O
R
Latch
Comp
R
Q
S
V_SW
Q_2
OSC
C_3
R
200
C_2
R_5
V_R
R_4
R_2
R_3
R_P
V_FB
R_1
Q_1
D_1
C_1
C_T
D_T
100
250
U_2
U_3
EA
150

Fig . 7

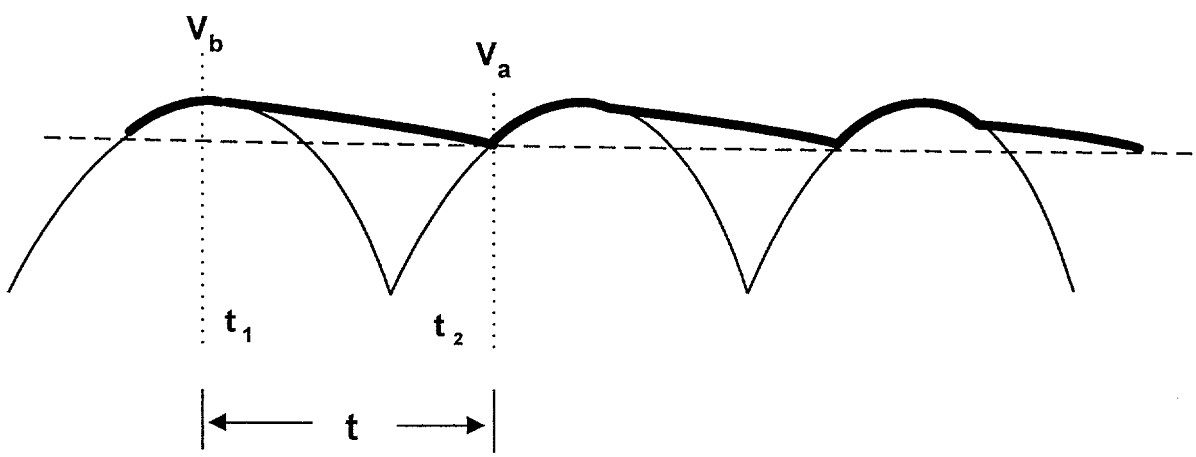


Fig . 8

BIRCH, STEWART, KOLASCH & BIRCH, LLP

COMBINED DECLARATION AND POWER OF ATTORNEY FOR PATENT AND DESIGN APPLICATIONS

ATTORNEY DOCKET NO. 3176 - 101P

PLEASE NOTE: YOU MUST COMPLETE THE FOLLOWING:

As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated next to my name; that I verily believe that I am the original, first and sole inventor (if only one inventor is named below) or an original, first and joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:*

Insert Title: Adaptive Slope Compensator for Current Mode Power Converter

Check Box If Appropriate - For Use Without Specification Attached:

the specification of which is attached hereto unless the following box is checked:

☐ was filed on ____________ as United States Application Number ____________ or PCT International Application Number ____________ and was amended on ____________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I do not know and do not believe the same was ever known or used in the United States of America before my or our invention thereof, or patented or described in any printed publication in any country before my or our invention thereof, or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (six months for designs) prior to this application, and that no application for patent or inventor's certificate on this invention has been filed in any country foreign to the United States of America prior to this application by me or my legal representatives or assigns, except as follows.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 (a)-(d) of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

Insert Priority Information (If appropriate)

(Number)	(Country)	(Month/Day/Year Filed)	Priority	Claimed
			☐ Yes	☐ No
			☐ Yes	☐ No
			☐ Yes	☐ No
			☐ Yes	☐ No
			☐ Yes	☐ No

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below.

(Application Number)	(Filing Date)

All Foreign Applications, if any, for any Patent or Inventor's Certificate Filed More Than 12 Months (6 Months for Designs) Prior To The Filing Date of This Application:

Country	Application No.	Date of Filing (Month/Day/Year)

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Number)	(Filing Date)	(Status — patented, pending, abandoned)

*NOTE: Must be completed.

I hereby appoint the following attorneys to prosecute this application and/or an international application based on this application and to transact all business in the Patent and Trademark Office connected therewith and in connection with the resulting patent based on instructions received from the entity who first sent the application papers to the attorneys identified below, unless the inventor(s) or assignee provides said attorneys with a written notice to the contrary:

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CHARLES GORENSTEIN (Reg. No. 29,271)
LEONARD R. SVENSSON (Reg. No. 30,330)
MARC S. WEINER (Reg. No. 32,181)
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PLEASE NOTE: YOU MUST COMPLETE THE FOLLOWING:

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P.O. Box 747
Falls Church, Virginia 22040-0747
Telephone: (703) 205-8000
Facsimile: (703) 205-8050

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full Name of First or Sole Inventor: Insert Name of Inventor Insert Date This Document is Signed

GIVEN NAME	FAMILY NAME	INVENTOR'S SIGNATURE	DATE*
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Insert Residence Insert Citizenship

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Residence (City, State & Country)	CITIZENSHIP

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Full Name of Third Inventor, if any: see above

GIVEN NAME	FAMILY NAME	INVENTOR'S SIGNATURE	DATE*

Residence (City, State & Country)	CITIZENSHIP

POST OFFICE ADDRESS (Complete Street Address including City, State & Country)

Full Name of Fourth Inventor, if any: see above

GIVEN NAME	FAMILY NAME	INVENTOR'S SIGNATURE	DATE*

Residence (City, State & Country)	CITIZENSHIP

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Full Name of Fifth Inventor, if any: see above

GIVEN NAME	FAMILY NAME	INVENTOR'S SIGNATURE	DATE*

Residence (City, State & Country)	CITIZENSHIP

POST OFFICE ADDRESS (Complete Street Address including City, State & Country)

*Note: Must be completed — date this document is signed.

(USPTO Approved 3-90)
(Revised 8-95)